

研究論文

The Research on Upgrading of China's Manufacturing Industry under the Background of Industry 4.0

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Abstract:

"Industry 4.0"¹ project has been proposed by the German government in 2013, the concept now has been widespread around the world. Many national governments have once again placed the transformation and upgrading of the manufacturing industry as the key task of this new round of industrial revolution. In recent years, developed countries have begun to put emphasis on the manufacturing industry as a trend. For example, the US government has launched a re-industrialization program, which costs hundreds of millions dollars each year to establish advanced manufacturing innovation institutes and make trainings for the senior technicians. With the trend of the strategic planning of the manufacturing industry in developed countries, Chinese government also has issued the "Made in 2025" strategic plan at the same time. In this strategic plan, Chinese government has pointed out the direction for Chinese manufacturing industry-how to transform and how to upgrade manufacturing industry. Why Chinese government attaches the great importance on "Industry 4.0", there may be two reasons: First, as the labor force is gradually decreasing in China, many researchers on manufacturing industry believe that "industry 4.0" which is characterized by intelligent and digital production may be the new way for further development of China's Manufacturing Industry. Second, there are many achievements of the German's manufacturing industry and the spirit of its manufacturing industry which Chinese enterprises should respect and admire. The above factors make the industry 4.0 project to be one of the most popular topic of China's Manufacturing Industry. However, the Chinese industry does not know clearly how difficult industry 4.0 project is and what should preparation for this new round of industrial revolution is necessary.

The goals of this research are: (1) to summarize the paths for upgrading and growth of manufacturing industry in developed countries;(2) to analyze the German's project "Industry 4.0" strategy path and its core, that is, "smart manufacturing" and specific operation models;(3) to put forward specific recommendations in order to seize the opportunity of the new industrial revolution.

Keywords: Industry 4.0; Made in China 2025; Upgrading of manufacturing

¹ "Industry 4.0" project has been funded jointly by the German Federal Ministry of Education and the Federal Ministry of Economics and Technology. The concept has been put forward by German Academy of Engineering, Siemens and other German academic, and the concept has formatted as one of the National strategies. Germany's federal government has invested more than 200 million euros. "Industry 4.0" strategy was officially launched at the Hannover Fair in April 2013, with the aim of improving the competitiveness of German industry and taking the lead in the new industrial revolution.

1. Introduction

Manufacturing related activities in global business are rapidly evolving. Manufacturing earnings and exports are stimulating economic prosperity which lead to focus on developing advanced manufacturing capabilities by investing in infrastructure² and education. Nations and companies are striving to advance to the next technological frontier and to raise their economic well-beings. And as the digital and physical worlds of manufacturing industry, advanced technologies have become even more essential to company-level and country-level competitiveness. In the 2016 GMCI, CEO survey respondents were asked to rank nations in terms of current and future manufacturing competitiveness. The study takes a closer look at 5 focus nations: United States, China, Japan, Germany, and South Korea. Collectively, these countries account for more than 50 percent of world's manufacturing GDP. These nations have great influence on global manufacturing trends.

"Smart manufacturing" is the core concept of German's strategy "Industry 4.0". The concept of "Smart manufacturing" is firstly proposed on the German conference in Hanover in 2011, and quickly spread around the world, as a new trend of global industrial revolution in the near future. In 2013, the German Federal Ministry of Education and the Federal Ministry of Economics and Technology have put "industry 4.0" project into one of the top ten future projects of German's "high-tech strategy 2020" and have planned to invest 200 million euros for supporting the technology research and innovation on further development in manufacturing industry. Specifically, German Association of Machinery and Manufacturers (VDMA) has established "Industry 4.0 platform" and "standardized roadmap" of the project "Industry 4.0". These actions show how to precede the project "Industry 4.0". The aim of the project "Industry 4.0" is to fully build intelligent production network, to promote the German manufacturing industry from the manufacturing process automation of "Industry 3.0" to the production process of intelligent and network by using information network communication technology and cyberspace virtual system (CPS).

The project "Industry 4.0" includes the construction of cyberspace virtual system (CPS).

CPS is based on the functions of computing, communications, precision control, remote scheduling and self-management. Then the construction of the "smart factory" and "intelligent production" will come true. The "smart factory" is a key component of the intelligent infrastructure in "Industry 4.0". Building "smart factory" should focus on the construction of the intelligent production system, the operation of the production management process and the networked distribution of production facilities. In addition, "Intelligent production" focuses on the human-computer interaction, intelligent logistics management, 3D printing and other leading technologies which are used in the process of the industry. Besides, along with the interoperability and relationship between the industries, research and development (R&D), manufacturing, procurement, marketing, logistics and other industrial chains, will combine knowledge and technology of related enterprises. A highly flexible, personalized, network-wide industrial chain will be built soon.

² Infrastructure includes transportation, post and telecommunications, water supply and power supply, business services, scientific research and technical services, landscaping, environmental protection, cultural and educational, health and other municipal utilities and public life service facilities. In modern society, the more economic development, the higher the demand for infrastructure. The construction of modern infrastructure is also increasingly in need of high-tech, such as high-speed rail technology and so on

The success of the first three industrial revolutions have enabled the world's developed countries, particularly Germany, to build and to manage complex industrial processes. In the third industrial revolution, the introduction of electronic information technology (ICT) into the process of modernization has successfully introduced into more than 90% of manufacturing processes in German enterprises. It has provided the opportunity for the establishment of information network communication technology and cyberspace virtual system (CPS).

Furthermore, American government has promoted the integration of information technology and intelligent manufacturing technology. To make technological innovation and intelligent manufacturing industry support each other, they have accelerated the platform installation of intelligent manufacturing. Japanese officials, among others, have issued “Robot New Strategy” and proposed three objectives in January 2015: Innovation bases of World robot industry; the first country to use robots in the world; The new era of the most advanced robotics industries in the world. The goal of South Korea is to enhance the competitiveness of manufacturing industry, to promote the integration of manufacturing and other industry, especially the information technology to create new industries³. South Korean government has issued “Manufacturing Innovation Strategy Implementation Plan 3.0” in March 2015. Chinese government has put forward the plan named “Made in China 2025” in May 2015 which aims to resolve the present problems of China’s manufacturing “big but not strong”, and “more without fine” . The plan clearly states top ten key areas for development.

Therefore, the “Industry 4.0” has provided a unique opportunity to promote the manufacturing industries. At present, China as the largest developing country, the development of its manufacturing industry not only embodies the general characteristics of developing countries, but also develops its own unique features. Thus, China urgently needs to change the current situation of manufacturing industry.

2. Theoretical Background

Industrial upgrading means to change manufacturing structure and create the added value in production process, including the improvement of production efficiency, product quality and the upgrading of industrial chain.⁴ Regarding Industrial upgrading, there are two kinds of research train. One is the adjustment of industrial structure; The other is the industrial value chain. Specifically, adjustment of industrial structure refers to change from labor-intensive to capital-intensive, then to technology (knowledge)-intensive. These researches put emphasis on macro-thinking based on many classical theories. Such as Lewis’s Dual Structure Theory, Nexus’s Poverty Vicious Circle Theory, Rodin's Theory of Great Advancement and Hirschman's Unbalanced Growth

³ New industries may come from the combination of internet, mobile Internet and traditional industries. Traditional retail and trade enterprises have developed new forms of e-commerce through the introduction of Internet. Traditional education with the use of new information technology has developed into E-Learning. The banking industry integrates with internet has developed into E-Banking. Jeremy Rifkin, professor of the University of Pennsylvania, in this new book which name is "the third industrial revolution", he says "whenever the emergence of new communications technologies or new energy technologies, or the integration of both the industrial revolution will take place." In Professor Rifkin's eyes the new industrial revolution maybe a new energy revolution.

⁴ The concept is from Chen shiqing , researcher of the Hong Kong Institute of International Education, life science researcher at the China Academy of Management Sciences.

Theory⁵. These theories demonstrate for developing countries how to accumulate investment funds, and how to attract foreign capital. Those actions could promote economic development. In different stages the contributions industrial structure, speed of industry's development and are different from ? to country, and different in timing of development situations. Hirschman argues that investment should be concentrated on the industries of high “forward-linkages” and high “backward-linkages”. The development of these industries could lead to the overall development of other industries. In brief, the existing literature of upgrading manufacturing industry can be summarized into three aspects: global value chain, foreign direct investment and service industry.

2.1 The perspective of global value chain in manufacturing upgrading

Gereffi (1999, 2005) has carried out research on global value chain to upgrade the manufacturing industry. According to his research, the manufacturing upgrading under the global value chain is defined as changes from low-value activities to relatively high-value ones in the global production network. The changes include the economic activities of countries, enterprises and workers. Pietrobelli & Rabellotti (2011) has considered that integration into the global value chain can enhance international manufacturing industry development, it also improves ability of learning and innovation for developing countries. Many empirical studies have also proved this point. Pavlinek & Zenka (2010) have spent the number of years 1998-2006 of Czech automotive industry, and their study has shown that making better of products and process plays an important role in upgrading industry and that joining global price value chain has promoted the Czech automotive industry towards further development. Contreras, Carrillo & Alonso (2012) s’ studies on the Mexican automotive industry show that the global value chain helps developing countries to learn the technologies of developed countries to promote industry. In addition, the developing countries in the global value chain, not only should learn advanced technology, but also need to focus on other factors. For example, Rasiah, Kong & Vinanchiarachi (2011) have argue in the Chinese button industry, the local government has made efforts to create the cooperation among government, enterprises and professional institutions. Tao Feng and Li Shitian (2008) have proposed that to integrate into the global value chain, Chinese manufacturing industry should follow the model “introduction to digestion and absorption then innovation”. Wu Qiang and Liu Zhibiao (2012) have shown from the Chinese practice in the relatively developed coastal areas, such as Jiangsu Province and Guangdong Province, the tendency of joining into the global value chain is more apparent than the tendency to joining into the domestic value chain.

2.2 The perspective of foreign direct investment in manufacturing upgrading

Lee (2009)’s empirical analysis of 25 OECD countries in the period 1975-2004 has shown foreign direct investment and trading are practically useful to the development of manufacturing industry. Takii (2011)’s study in Indonesia has shown that foreign direct investment from East Asia has contributed positively to the growth of manufacturing in Indonesia. Since reformation and opening up, China has been committed to attract foreign

⁵ Organize from Bai Yongxiu, Hui Ning. Research on the Basic Problems of Industrial Economics. China Economic Publishing House, 2008 and Yang Gongpu, Xia Dawei. Industrial Economics. Shanghai University of Finance and Economics Press. 2008

direct investment to promote the development of manufacturing industry, and FDI in China has presented different characteristics. Li Shanshan (2012)'s research has shown that FDI has a significant spillover effect on the coastal manufacturing industry, but for central and western regions, there is no significant technological spillover effect. Huang Lingyun and Wu Weijiong (2013) have proposed that the effects of FDI are different from industry to industry, FDI can significantly promote the development of low-tech industry, but not useful to high-tech industry. It should be noted that, in some industries, foreign direct investment may bring negative influences. For example, Chen Yongjun and Yang Zhen (2012) have shown that the competition effect of foreign investment is dominant. But in automobile industry FDI has shown anti-competitive effects (monopoly). Wang Ziwei (2009) has shown in the whole Chinese vehicle industry, the crowding out effect of foreign direct investment has exceeded the spillover effect.

2.3 The relationship with service industry in manufacturing upgrading

With the rapid development of modern information technology and the integration of manufacturing industry, service industry has got to the mainstream development trend. Coffey & Bailly (1997) have considered that service industry can promote flexible production in the manufacturing industry. Xuan ye (2012) and Qiu Xiaohuan (2011) both have agreed that service industry can help manufacturing industry reduce the production and transaction costs through the competitive and specialization of service and external activities. It is an effective way to improving the competitiveness of manufacturing industry. Gao Chuansheng and Liu Zhibiao (2005) have verified service industry can promote agglomeration of manufacturing industries. Qiu Xiaohuan and Huang Jianzhong's study (2011) has shown that service industry has taken positive effect in the export expansion. It is observed that manufacturing industry and service industry support each other. With the expansion of international trade, technical differences between the final products and service level have become key to success in international market. Francois & Woerz(2008) have thought that service outsourcing can effectively raise the international competitiveness in high-skilled manufacturing industry.

3. Practical background of the main manufacturing countries

In the 2016 GMCI (Global Manufacturing Competitiveness Index), the study has taken a closer look at five focus nations: United States, China, Japan, Germany, and South Korea. According to the statistics, these five countries have accounted for more than 50 percent of world's manufacturing GDP. Therefore, the development of these five countries can demonstrate the global manufacturing trend to a certain degree. Each countries' manufacturing industry has its own characteristics, so the development of manufacturing industry of those countries aren't the same. In United States, the developing trend is the tight integration of manufacturing industry and service industry. It has shown up as the combination of cutting-edge technology and new business models. With a view of development, American manufacturing industry has laid stress on the innovation of market creation. For example, IBM which was born in the US, its mainframe accounted to thousands of dollars over a long time, only a few people could afford it. Now, under the concerted efforts, the PC's price has reduce to under

\$200. American manufacturing firms have aptitudes for radical innovation for complex products. To increase output and to reduce costs, the manufacturing enterprises in the US are inclined to enhance their design capacity and to innovate their business models, thus to attract more customers and expand markets. In Japan, manufacturing industry, the most outstanding feature may be the strict and precise control in the workshop scene. Toyota's famous zero inventory production system has made the inventory cycle decline to two months, it has improved the capital flow in the whole company. It can be perceived that process innovation has brought great benefit in Japanese manufacturing industry. Korean manufacturing industry is deft at modular architecture of capital-intensive products. And the development in Korean manufacturing industry would be inconceivable without the investing of high-tech industry. Germany is apt at cutting-edge technology, intelligent manufacturing equipment, process management and technology application. These features have made sure that German has taken the leading position in global manufacturing industry.

German industrialization process begun later than other developed countries in Western Europe, but eventually became as a top manufacturing power. So the successful experience of the development in German manufacturing industry could be conveniently referred for this research object-China.

4. The development of German manufacturing industry and "industry 4.0"

Germany and China are both big manufacturing countries and exporting countries but the two countries are far apart in the level of manufacturing industry. German always keeps the leading position in global manufacturing industry. Because of Schumpeter's innovation-driven theory, German has used progressive innovation policies to develop high-level manufacturing industry and has changed business models, they are not only focus on the innovation system for construction of the whole country's manufacturing industry, but also stress on the transformation of patents. Making inventions generate real economic value. In the past years, "Made in Germany" has grown stronger and stronger and has become a trusted international image. In 2008 under the economic crisis, the German economy is "thriving" by virtue of safe, reliable, sophisticated, durable and world-renowned German manufacturing industry. German manufacturing industry has supported the continuous development of the national economy, and even propped up the entire European economic revival hope. Although German has become the EU's most dazzling economic star, but looking things from Germany perspective, German has faced some internal and external problems in fact. In the manufacturing industry, German has strong competitors, including the traditional manufacturing giants (US and the other developed countries) and the newly emerging developing countries. German Chancellor Angela Merkel has pointed out that 90% of the innovation is generated outside Europe, Europe cannot miss the next industrial technology revolution. Merkel also worries about whether the German manufacturing industry could timely connect with the modern information and communication technology. It may determine whether the Germany will be able to continue its technological leadership. The United States, Britain, France, Japan, South Korea and other countries have developed a series of planning and action to make further development of manufacturing industry. More and more strong opponents, the market size

remains the same, the German enterprises face more competition. "Industry 4.0" project has been proposed to respond to this challenge.

4.1 The presentation of The German project "Industry 4.0"

The German project "Industry 4.0" is designed to take full advantage of the combination of ICT (Information Communications Technology) and CPS (Cyber-Physical System) to promote the intelligent development in manufacturing industry.

German academia and industry both believe that the development of CPS will lead to the intelligent manufacturing industrial revolution in the next 10 years. In this intelligent revolution, Internet of things and Internet of services will penetrate into all key areas and processes. The process of creating new value gradually change. The division of labor will be reorganized and the traditional boundaries of the industry will disappear. CPS is the foundation of industry 4.0. It consists of three parts: intelligent machines, storage systems and production facilities. CPS can be integrated into manufacturing process and logistics process, then it establishes highly flexible production model and provides personalized service and realizes intelligent manufacturing at last. Intelligent manufacturing which is based on CPS can enhance manufacturing competitiveness from three aspects: ① The mode of production will change from "centralized" to "decentralized" with CPS. Production factors can be allocated without delay to ensure the flexibility of the process and resource utilization. ② CPS could enable customers and business partners to participate in value creation process. CPS-based production process has lowered the barriers between virtual world and physical world. Customers and business partners can participate more directly in the creation of business value process. ③ CPS can exchange messages automatically and independently trigger action and control, so to achieve the self-organizing production model. To change the workers from the operational task to innovative design, control and other high value-added work.

The completion of the first three industrial revolution, especially the third one, has provided a base of the fourth intelligence industrial revolution for Germany. It has introduced the information and communication technology (ICT) in the third industrial revolution. As a result, the manufacturing process is constantly being automated, the machines not only took over a considerable proportion "manual labor", but also took over a number of "mental work." ICT has made those different tasks be carried out by partners in different geographical locations, so that organizational and coordination ability has improved, the cooperation enthusiasm and efficiency has significantly raised in German manufacturing industry. Now ICT has already entered more than 90% in German industrial manufacturing process, more and more IT infrastructure and services will provide by networking (Cloud computing). It is the precondition for the establishment of CPS.

4.2 The development of German manufacturing industry

In addition, the history of the development in German manufacturing industry can also provide a good reference for Chinese manufacturing industry. German manufacturing can develop with the following aspects. Those are perfect logistic facilities, continuous technical innovation and competitive education system.

4.2.1 Perfect logistics facilities

Transport conditions are the basis of industrial development, Germany has the longest railway (33,721 kilometers) in the European Union. With the increasing number of railway miles per year, there are the rapid development of the German coal industry, iron and steel industry, which have contributed to the development of the German machine-building industry. Besides railways, the length of highroads is more than 1.26 million kilometers, ranking second in the world. The added value of the automobile industry in Germany accounts for about 1/5 of total GDP, the development of highway is the basis of automobile manufacturing industry. What is more, German federal waterway is about 7,500 kilometers long with 100 modern public harbors and river ports. Frankfurt Airport is one of the world's most important airports, every minute hundreds of flight ups and downs. German shipping, water transport and land transports are in complementarity and coordination with each other to ensure that the products have been provided in efficient and low-cost way to the whole world. Transport conditions in Germany has ensured the development of manufacturing industry.

4.2.2 Continuous technical innovation

The research of German Fraunhofer Institute has shown that the speed of German manufacturing industry introducing new products is almost as fast as the information industry. It is closely related to R&D input of German manufacturing enterprises. In 2012, R&D investment in German manufacturing industry (including automotive, electrical, machinery manufacturing, chemical and the other manufacturing enterprises) has hit nearly 40 billion euros. In the German innovation system, the government and industry associations have played important roles in technical innovation. The German government attaches great importance to the full extent of competition in the manufacturing industry market in order to ensure the speed of new technological diffusion. The German government also supports the development of small and medium enterprises, to encourage entrepreneurship and establishes a sound social security system for the jobless people. The more perfect environments (including patent protection, intellectual property system, R&D supporting, tax relief and other forms) may stimulate technical innovation. The VDMA (a German trade association) has about 3,000 machinery and equipment manufacturers as members, providing timely and effective information on new technologies and services to the industry. Furthermore, the government vigorously promotes the cooperation between universities and enterprises, and establishes a lot of science and technology parks and technology incubation centers. This is helpful to transformation of scientific achievements.

4.2.3 Competitive education system

German higher education attaches great importance to the natural science and engineering subjects, in addition to the traditional comprehensive universities, there are many industrial technology schools in Germany. It emerged in the 1960s. With short learning system and close cooperation with enterprises, these technical schools are welcomed by students and employers. German unique "dual-track"⁶ vocational training system has

⁶ German dual-track vocational education is a combination of schools and enterprises. There are more than 350 kinds of skills training, students can spend one-third of the time in the school to learn theoretical knowledge, two-thirds of the time on internships and trainings in the related enterprise.

cultivated a large number of well-trained professional technicians for the German manufacturing industry. The success of German manufacturing industry cannot be separated from a large number of experienced and highly skilled technical workers. The average wage of skilled workers in German manufacturing industry is much higher than that of same developed countries, it is almost equal to the income of white-collar workers. Except for these, German also has clear legal requirements: Vocational training is required for any work. Without a vocational training certification people cannot find jobs. Under these measures, employees can solve not only practical problems as soon as possible, but also can bring technological innovation for enterprises. Universal vocational training has improved the professional skills and practical skills of staff and provided a good reserve for the development of the German manufacturing industry.

5 The status quo of Chinese manufacturing industry and recommendations

Over 40 years of effort, China has rapidly developed into the world's second largest economy. Chinese manufacturing industry output exceeded the United States in 2011. But China still faces a lot of problems in manufacturing industry. On the one hand, the cost advantage in Chinese manufacturing industry is constantly losing, India, Vietnam and the other developing countries have more advantages in the low-end manufacturing with lower cost on transportation and labor force. On the other hand, in order to revitalize the employment rate and enhance people's confidence in developed countries, some western countries are transfer manufacturing investment and production from overseas to domestic. Undeniable, developed countries have relayed on capital, technology, human resources and marketing to occupy high-end in global industrial chain. On the contrary, many Chinese manufacturing products are still with low value-added. In the global profit distribution of manufacturing industry, China can only get a small part of the value in the chain. So China should learn from the German experience in the new round of industrial revolution to raise the level of the manufacturing industry. Chinese manufacturing industry can be enhanced in the following areas:

First, German manufacturing industry has been well developed, the main driving force may be the governments, and they have provide the windscreen protection for enterprises. In 1957, the Federal Parliament putted out "Restriction of Monopoly Law "in order to protect the fair competition and anti-monopoly of enterprises. Although China has long been with the relevant laws, but the practice should be further strengthened. Especially in some large state-owned manufacturing enterprises, it needs introduce relevant policies to ensure fairness and competition in this industry.

Second, the developed countries which have strong manufacturing power control the core technics in special fields. Compared with the manufacturing developed countries, Chinese manufacturing innovation index (such as the number of researchers per million population, contribution of employees to GDP) has a certain gap. Therefore, Chinese manufacturing industry should expand investment in technological research and improve the independent innovation ability.

Third, creating high-quality manufacturing brands should be a potential way for development. Brands are

essential to market competition. Brands show influence on market share and customer loyalty in some extent. Now, the number of world's top brands has become an important indicator of manufacturing strength. Chinese manufacturing industry should strengthen brand awareness. For the brands which already have high visibility and influence in domestic market, they should focus on expanding their international influence. Some strong manufacturing enterprises should conditionally purchase (M&A mergers and acquisitions) overseas brands which already have certain international influence. But there are still some problems after M&A for Chinese manufacturing enterprises, consumers do not realize the bought brand has changed the manufacturers. The phenomenon shows M&A of famous international brands does not achieve the desired objectives. So industry manufacturers need further innovation on the bought brands to make the brands with some Chinese characteristics.

Fourth, with the development of intelligence manufacturing, the future manufacturing industry will greatly change the production way of workers and their skills. Enterprise as the third largest research base (including universities and independent research institutes) is an important source of R&D funds and the main promoters in independent research development and technological innovation. It is important to strengthen the training of staff and to build up the concept of lifelong learning. For China, higher education has grown rapidly, vocational education also needs more space to develop. And vocational schools should continuously improve the professional competence of teachers to meet the needs of the future development of the manufacturing industry.

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